FINAL Report

to

NASA GRC

for the

NExTNAS – CNS WORKSHOP

Task Order 6

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I. EXECUTIVE SUMMARY

NASA Glenn Research Center in Cleveland, Ohio held a two day NASA NExTNAS CNS Workshop on August 20-21, 2003. The Workshop's objective was to present NASA's Project Plan under the new NASA Exploratory Technologies for the National Airspace System (NExTNAS) Initiative: for advanced communications, navigation and surveillance (CNS) system research and development in support of modernization of the National Airspace System (NAS), and to seek comments from relevant members of the aviation community.

With the NExTNAS-CNS Project, NASA is responding to: recommendations from the US Aerospace Commission, the US aviation community (ICNS 2001, 2002, 2003), and studies/analyses that demonstrate the need for an advanced CNS infrastructure to address system deficiencies and support the transition to the future NAS. Three major goals were addressed. **NASA's Airspace Systems Program** goal is to enable major increases in the capacity and mobility of the air transportation system through development of revolutionary concepts for operations & vehicle systems. The **NExTNAS initiative** is to develop technologies, procedures and information infrastructure to enable further system capacity/throughput improvements. The **NExTNAS-CNS Project** goal is to initiate the transition of today's CNS systems into a high-performance network-centric digital infrastructure to support the transformation of the National Airspace System.

Finally, NExTNAS-CNS planning activities and workshop objectives were presented. Four major objectives were discussed. 1) Present background of the NASA Airspace Systems Program and overviews of relevant Airspace initiatives. 2) Present an overview of the current NExTNAS-CNS Project plan. 3) Gather input from the aviation community: comments and suggestions on plan content; inputs on approach, outputs, etc. 4) Present and identify opportunities for participation: stimulate collaboration, partnerships and other potential future relationships (contractual and otherwise).

II. INTRODUCTION

Computer Networks & Software, Inc. (CNS) is providing this report in response to the NASA Glenn Research Center's (GRC) Task Order 6 for the NExTNAS-CNS Workshop. The Workshop was conducted on August 20-21, 2003. For the task of recording the results of the Workshop, CNS assigned the following personnel: Plenary – David Somers/Gregory Jones; Session A: CNS Architectures and Networks – David Somers; Session B: VHF System Technology and Next Generation Digital Communications – Vikash Srivastava; Session C: Multi-Function/Multi-Mode Digital Avionics – Crispin Netto; Session D: Oceanic Communications/Surveillance and Future Space-Based Surveillance – Gregory Jones; Session E: Surface Integrated CNS Network – Manu Khanna; and Session F: Aviation Spectrum Issues and Solutions – Paul Meredith. This same team successfully completed a similar role at the 2003 ICNS Conference on May 19-22, 2003 in Annapolis, Maryland.

1. Background

NExTNAS is a set of Airspace Systems Program new (FY '04-08) projects that will act upon the goals of the Airspace Systems Program: Improve throughput, predictability, flexibility, collaboration, efficiency and access of the NAS; while maintaining system safety, security and environmental protection. There are five NExTNAS Research areas: Advanced CNS, Wake Vortex Solutions, ATM Automation Technology, Demand Adaptive ATM and Human Measures & Performance.

2. Scope

NExTNAS-CNS goals, objectives and products are based on the following: 1) Knowledge and experience gained by NASA Glenn from its long history of work in advanced communications technologies and more recent work in Aeronautical CNS projects; 2) Requirements analyses, architecture studies and Technology Gap analyses; 3) Integrated CNS technologies conferences and workshops; and 4) Technical interchange meetings (TIMs) with industry and the FAA.

In support of the NExTNAS-CNS Project, NASA has implemented the following philosophical concepts and guidance as a roadmap for the Project. 1) NASA's role is primarily research and development, rather than engineering, implementation and operations. 2) NASA has a role to provide the FAA and industry with long-term research and development needed to guide the evolution of the NAS. 3) NExTNAS planning must be cognizant of other initiatives in the planning stage (i.e. Skypath 2020) that have a more far-term research orientation. 4) The following is NExTNAS-CNS's position within Advanced CNS research plans: (a) A balance of near/mid/far term products = low/mid/high TRL; (b) Emphasis on more near term, high TRL deliverable products that will enter the system. NASA will need to show relevance and visible, implemented outcomes.

3. Workshop Agenda and Leadership

Attachment 1 and 2 provides the NExTNAS–CNS Workshop 2003 Agenda in addition to a listing of the individuals providing presentations and leading the various workshops.

4. Activity Overview

The NExTNAS-CNS project is a new FY04-FY08 project within NASA's Airspace Systems Program. The Project's Goal is to identify and begin the transition of NAS CNS systems to a high-performance network-centric digital CNS infrastructure, while addressing near/mid-term issues within this transition context. Ten sub-projects were analyzed/reviewed at this workshop. It is a goal that these projects be substantially defined during the first year of the project. These projects also represent a balance of near, mid and far term research. Another goal is for several "high-TRL" products to be ready for the start of an implementation process by the end of the project.

A short description of each session follows:

Session A: CNS Architectures and Networks Proposed research efforts in CNS architectures that will provide the transition from current plans to the transformational NAS CNS architecture of the future, and the underlying network technologies enabling system-wide integration and global interoperability.
Session B: VHF System Technology and Next Generation Digital Communications Proposed research efforts aimed at improving operational and spectral efficiency for current and emerging VHF communications and at defining the next-generation digital air-ground communications for terminal area applications.
Session C: Multi-Function/Multi-Mode Digital Avionics continues the discussion of needs, requirements and approaches for developing multi-function, multi-mode, digital avionics that began at the 2003 ICNS Conference, and develop details of potential architectural and technical approaches.
Session D: Oceanic Communications/Surveillance and Future Space-Based Surveillance Proposed research and development efforts to enable improved communications and surveillance for oceanic and remote areas aimed at allowing safe reduction of aircraft spacing for those environments, and the potential for new space-based surveillance technologies to provide significantly improved surveillance performance for national and global airspace.
Session E: Surface Integrated CNS Network Proposed research and development efforts for an integrated CNS data network for the airport surface, enable data transfer among users, service providers and surface management applications.
Session F: Aviation Spectrum Issues and Solutions Aviation spectrum issues, approaches, and research needs.

III. PLENARY REPORT

1. Introduction/Welcome

The NExTNAS-CNS Workshop was kicked-off with introductory comments from Don Campbell, Center Director of NASA Glenn Research. He started by stating that there is a shift in the communications area at Glen. Today, the emphasis is performing research work in the advanced communication arena. By this Don mentioned that we needed to focus on the capability to provide more knowledge, integrate it with other sources and forward this enhanced communication to both aircraft and controllers working with aircraft. He recommended that the research/aviation community look at this challenge as a holistic problem. In addition to communications, Don mentioned additional focus will be placed in the areas of navigation and surveillance. He stated that he was looking forward to innovative, technical ideas/tools/solutions from the entire community.

Don mentioned that the future activity at Glenn will shift from space communication to aviation communication. Aviation communication will be the next step in the future focus of NASA

Glenn research effort; however, the center will still continue its work in the space arena, but only to a lesser extent. Don ended his comments by stating he was looking forward to the efforts of the entire team as we address the challenges of advanced communications in the future.

2. Presentation Report 1 (Workshop Overview/Objectives)

Bob Jacobsen, Program Manager for NASA's Airspace Systems Programs started the presentations with a Workshop Overview and Objectives, **(Attachment 3)**. NASA's NExTNAS initiative is to develop and demonstrate NASA exploratory technologies for the NAS to meet projected growth in passenger demand beyond 2010. With the NExTNAS-CNS Project, NASA is responding to: 1) recommendations from the US Aerospace Commission, 2) the US aviation community (ICNS 2001, 2002, 2003), and 3) studies and analyses that demonstrate the need for an advanced CNS infrastructure to address system deficiencies and support the transition to the future NAS. A goal is to look at the system capacity and mobility, and then provide emphasis on revolutionary concepts that define how to implement in an evolutionary fashion. In addition, identifying the appropriate users of the NAS is necessary to be able to relieve congestion.

NExTNAS-CNS planning activities were provided. Bob stated the program is time constrained compared to a typical project; expect FY 05 start. In support of this activity, several projects has provided information to build upon (i.e. requirements analyses, architecture studies, etc): 1) AATT – Advanced Communications for Air Traffic Management; 2) AvSp – Weather Information Communications; 3) VAMS – CNS Modeling; and 4) SATS – Airborne Internet. In addition, three Integrated CNS Conferences and Workshops (2001, 2002, 2003) have provided significant input to the program. A plan activity schedule was presented with emphasis on today's workshop being a continuation of the current planning effort.

3. Presentation Report 2 (Airspace Systems Overview)

Bob Jacobsen also presented charts for this session, **(Attachment 4)**. NExTNAS is a set of Airspace Systems Program new (FY '04-08) projects that act upon the goals of the Airspace Systems Program. There are five NExTNAS Research areas: 1) Advanced CNS – Glen; 2) Wake Vortex Solutions – Langley; 3) ATM Automation Technology – Ames; 4) Demand Adaptive ATM – Ames; and 5) Human Measures & Performance – TIMs with Industry, Government and Glen. Another project was presented called TNAS (SKYPATH). This is a new project in response to the National Plan of the Joint Planning Office (JPO). The JPO receives guidance from the Policy Board (oversight by DOT Secretary Minetta), which is performing strategic planning thru FY 2025. The JPO then writes a National Plan based upon inputs from several agencies: FAA, NASA, Department of Commerce, DoD and Department of Homeland Security (DHS). The goal is for each agency to develop their individual plans to fulfill specific requirements. This is a flexible document in that proper adjustments will be made based upon activity that facilitates a higher priority.

The following program schedules were presented to provide a roadmap for research activity.

1. AATT: FY 96 – 04
2. VAMS: FY 02 – 06
3. SATS: FY 01 – 05
4. AOS: FY 00 – 06

All of the above listed programs/projects will provide an opportunity to provide valuable input into the NExTNAS-CNS program: FY 04 – 08.

An estimated funding profile chart was presented indicating: FY 04 approximately $4M; and FY 05 approximately $12.5M. In addition, Bob presented the various procurement strategies (total of 7). His presentation concluded with an overview of the ten sub-projects to be discussed during this Workshop. A comprehensive summary was provided for each area, along with a listing of the Technology Readiness Level (TRL) and Implementation Readiness Level (IRL). Upon reaching TRL level 6, the project is turned over to the FAA for implementation.

4. Presentation Report 3 (FAA/NASA IAIPT Overview)

Bill Bradford (FAA) presented the charts for this session (Attachment 5). The Interagency Integrated Product Team (IAIPT) mission was provided: Plan and conduct integrated FAA/NASA air traffic management research and development leading to implementation of operational concepts; and associated decision support tools, which will enhance the safety, efficiency, and flexibility of the operations for the current and future NAS. This partnership began on September 11, 1995 when the FAA and NASA signed a MoU on Airspace System User Operational Flexibility and Productivity to plan and conduct integrated ATM R&D. Several organization and Structure charts were then presented.
The IAIPT Management Team (Volpe, Lincoln Labs, Mitre) has introduced two new teams: Weather and CNS R&D Work Teams. Candidate activities for both teams were discussed, including additional emerging activities through the JPO. Three Next Steps were provided: 1) Restructure IAIPT in order to efficiently accommodate new areas of responsibility; 2) Stage the introduction of Weather and CNS research into IAIPT; and 3) Await developments with respect to working with the JPO.

5. Presentation Report 4 (FAA Target Systems Description)

Anne Tedford (FAA) presented the charts for this session (Attachment 6). The Target System Description (TSD) is part of the FAA modernization of the NAS, to enable the achievement of a Joint CONOPS. The TSD describes how far the FAA expects to get by 2015: systems implemented, services provided and operational capabilities achieved. The purpose of TSD is for the planners (JPO, Boeing) exploring the future (Beyond 2015) need to have a realistic estimate of where the Joint CONOPS will be achieved. Also, TSD will ensure that the FAA modernization efforts are prioritized and focused to achieve the desire operational goal.
Several charts were presented describing the TSD relationship with other NAS plans, plus an overview of the TSD development process. Five major areas involved with TSD are 1) Terminal (Arrival/Departure), 2) En Route/Oceanic (En Route), 3) Surface (Tower), 4) Traffic Flow

Management (TFM) (Strategic Flow); and 5) Flight Advisory Services. Specific architecture charts plus a future system program summary (including funding status) was provided for all areas. In addition, the Enabler domain areas presented included: 1) Automation; 2) Communications (G/G, A/G, Data Link); 3) Navigation; 4) Surveillance (all sources); and 5) Weather. A cross-matrix series of charts were presented providing the major TSD areas along with the various programs associated with each. Finally, a comparison chart was discussed showing the 10 CNS Project Technology areas and their related TSD System. Anne closed with a chart providing TSD Information locator on the Web for additional review if desired.

6. Presentation Report 5 (NExTNAS-CNS Project Overview)

Robert Kerczewski presented the charts for this session **(Attachment 7)**. The goal of this session was to set the ground work for the break out sessions. Background information and project goals were presented. The major portion of this session involved a detailed discussion of each of the ten Subprojects. Problem statements, objective, product description and schedule were provided. In addition, the NExTNAS-CNS funding profile was also discussed. The session ended with discussion on procurement strategies and a final project summary.

7. Presentation Report 6 (Break-Out Session Overview & Directions)

Robert Kerczewski presented the charts for this session **(Attachment 8)**. The objective of this session was to provide guidelines for the breakout sessions introduce the session chair-people and discuss the format for the presentations.

8. Question/Answer Discussion

A question was asked regarding the FAA decision to forward benchmark technologies, and technology insertion opportunities, such as Long Range Radar. NASA currently has a “Push/Pull” relationship with the FAA. FAA provides the initial “Push”, but a larger emphasis on current projects is the “Pull” concept. FAA identifies to NASA the areas where they do not have solutions. The FAA’s current “Push” is towards Global operability in the international community. Security was also mentioned in that it is currently focused on aircraft. It was mentioned that this concern should be addressed in a forum such as a long-term integration plan.

IV. WORKSHOP BREAKOUT SESSIONS REPORT

1. Overview of the Workshop Breakout Sessions

The highlight of the NExTNAS-CNS Workshop was the Breakout sessions. Attendees had the option to choose a session to participate in. The following provides the session titles along with the name of the session chairs. Session A: CNS Architecture and Networks (Art Feinberg, Cal Ramos); Session B: VHF System Technology and Next Generation Digital Communications

(Tom Mulkerin, Mike Zernic); Session C: Multi-Function/Multi-Mode Digital Avionics (Frank Mackowick, Jim Budinger); Session D: Oceanic C & S and Future Space Based Surveillance (Ricardo Parra, Gus Martzaklis); Session E: Surface Integrated CNS Network (Marty Pozesky, Rafael Apaza); and Session F: Aviation Spectrum Issues and Solutions (John Zuzek, David Matolak). Specific questions were addressed and a formal presentation was provided by each group.

2. Session A: CNS Architectures and Network

2.1. Identification of the Session Chair(s)

Session A was co-chaired by Art Feinberg of (AMA) and Cal Ramos of NASA Glenn Research Center (GRC).

2.2. Purpose

The purpose of the break out session was to propose research efforts aimed at improving specific architecture and network products/concepts, discuss specific issues, attributes and qualities; identify the value of a network-centric architecture, security, integration and finally define an integrated technology roadmap tied to other architecture planning initiatives.

2.3. Members

Name	Affiliation
Art Feinberg	AMA
Greg Kubat	Analex Corp.
Harold Brackett	Harris Corp.
Russell Chandler	Lockheed Martin
Darlene Pitts	Volpe/CSC
Bob Crow	AIRNAV
David Buis	Boeing
Jim Rogers	FAA
Mark Freeman	DOT/Volpe
Terry Wiblitzhouser	Boeing ATM
Bill McNary	AeroSat Corp.
Aknesha Miller	Lockheed Martin TSS
Steve Bussolari	MIT Lincoln Lab.
Frank Frisbie	Northrop Grumman IT

Name	Affiliation
David Cohen	TSC
Bill Burdette	Planning Systems Inc.
Allen Oliver	Zin Tech.
Kathy Liszka	GRC/Univ Akron
Scott Seifert	Trios Assoc.
Michael Hadjitheodosiou	Univ of MD
Spyro Papademetriou	Univ. of MD
Rich Slywcak	NASA/GRC
Mike Heryak	NASA/GRC
Marc Viggiano	Sensis Corp
Tann Pinney	AMTI
Vicki Cox	FAA
Gary Weegmann	NASA/GRC
Noel Schmidt	Arch. Techn. Grp
Peter Harbath	Analex Corp
David Steward	Verizon FNS
Janet Mackett	ViaSat Inc
Chris Dhas	CNS
David Brooks	RSIS
Matt Blake	Seagull Tech., Inc.
Olga Quiles	NASA/GRC
Harry Part	CSC
Steve Mainger	NASA/GRC
Harry Swenson	NASA Ames RC
Ryan Wilkins	IGI
Stephane Mondoloni	CSSI, Inc
Bill Colligan	CSSI, Inc.
Theresa Benyo	NASA/GRC
Jeff Brabender	Coherent Solutions
Vijay Konangi	Cleveland State Univ.
Karla Watson	Jeppesen Sanderson
Brian Kachmar	Analex Corp
Tom Kacpura	Zin Tech
Muli Kufle	NASA/ GRC
Frank Merat	Case Western Res Univ
James Czechanski	Trios Assoc Inc
Scott Seifert	Trios Assoc Inc
Kevin Harnett	DOT/Volpe

2.4. Discussion Report

The major point of initial discussion in the breakout session was centered on the objectives of the session. The process that was followed consisted of: a review of the Architecture Workshop results from the Third 2003 ICNS Workshop; and an overall review of architecture and network subproject plans. Feedback was solicited from the entire group at large, additional feedback was solicited individually, and a broad range of discussion themes occurred.

The following discussion points/themes were addressed: review of proposed plans; revisit problems/needs/requirements/desired outcomes; best approach goals; relevant work currently being performed; potential partnership to be formed; capture ideas, test and demonstrate requirements & approach; and capture ideas of other relevant CNS technologies.

Seven major discussion topics were addresses: Vision and Strategic direction, Approach, Security, Integration of CNS systems, Transition, Architecture Validation and Technologies.

Vision & Strategic Direction. Four themes were discussed: a vision that defines an end state is needed to provide context for program and its elements (i.e. Vision: 3 times current capacity); a need for identification of requirements that current CNS will not meet; value of network-centric architecture must be shared; discussion on the underlining CNS infrastructure to support autonomous requirements; and the problem statements are not sufficiently scoped – they are too broad in nature.

Approach. The majority of the breakout discussion involved this area. Several areas were discussed: CNS architecture must be tied into an overall "Enterprise", high level architecture (includes application requirements); what drives CNS Project – Requirements vs. Technology; effective and detailed requirements analysis is critical; proposed technology based approach in parallel with requirements; a needed leverage advancements in ground based systems/architecture; comprehensive standards effort will be needed; the importance of a good business case/CBA; a requirement to tie into RTCA CONOPS and requirements of DHS and DoD; a Technology Roadmap is needed; and a need to leverage efforts in TCA and Space initiatives.

Security. Four themes were discussed: architecture needs to address the security issue; the challenge is to provide secure data in "real time"; there is a real need for integrity of information and the ability to monitor intrusion detection; and the need to leverage commercial based technologies/systems.

Integration of CNS Systems. Four areas were addressed; risks need to be identified; we need to evaluate the "hidden attributes" of current "stove-piped" systems; the need for information sharing to the max extent possible – more information available leads to additional benefits; and sensor fusion and integration are needed to provide situational awareness.

Transition. Five themes were discussed. It was acknowledged that this process would be a very slow process. The group concluded that we must recognize the fact that the existing architecture planning will provide for future evolution. "Human element drives slow change. A minimalist approach is critical for aircraft users. Finally, the importance of wireless implementation for Surface applications was noted.

Architecture Validation. There will be an extensive large scale modeling and simulation effort needed. It was recommended that we partner with DFAC for testing and demonstration.

Technologies. Three topics were addressed: Quos, security and encryption technologies need to be evaluated; NASA/GRC should become involved with in GPS-3; and look at 3G Wireless and possibly partner with manufactures and service providers.

2.5. Session Out Briefing Report

Art Feinberg (AMA) made the final presentation. The briefing material is provided in **Attachment 9.**

2.6. Conclusions and Major Themes Summary

Key deliverables were presented:

- A validated CNS Architecture is needed that will support future NAS Infrastructure Vision to include
  - A validated range of CONOPS
  - Large-scale Simulation and Emulation
  - High level system requirements for future NAS technology development
  - An Integrated Technology Roadmap that is tied together to other architecture and planning activities

Additional comments were provided:

- Academia should be working on low TRL studies focusing on modeling/simulation of topologies and traffic patterns for various applications requirements (Top-down approach)

- The Industry approach should address security, economy, integration through use of hybrid communication architectures

3. Session B: VHF System Technology and Next Generation Digital Communications

3.1. Identification of the Session Chair(s)

Session B was co-chaired by Mr. Mike Zernic of NASA Glenn Research Center (GRC) and Tom Mulkerin (MAI).

3.2. Purpose

The purpose of the break out sessions was to propose research efforts aimed at improving operational and spectral efficiency for current and emerging VHF communications and defining the next generation digital air ground communications for terminal area applications.

3.3. Members

Name	Affiliation
Mike Zernic	NASA
Tom Mulkerin	MAI
Gerald Chomos	NASA
Chris Wargo	CNS
Prasad Nair	PMEI
Monty Andro	NASA/GRC
Kathleen Kearns	SITA
T.C. NGUYEN	ANALEX
Steve Bretmersky	CSU
Dave Hammerick	Mitre/CAASD
Andy Oltmanns	Northrop Grumman
Don Hilderman	NASA
Tom Hagen	
Erik Roberts	Analex
Darlenen Pitts	VOLPE/CSC
Mark Freeman	VOLPE
Darlenen Pitts	VOLPE/CSC
Mark Freeman	VOLPE
Kue Chun	NASA/GRC
John Coy	NASA Ames RC
Gene Fijikara	NASA
Thomas Tang	OAI
Chuk Laberge	Honeywell
David Matolak	Ohio University
Felix A.	NASA
Mohammed Shama	ANNALEX/NASA
Ben Noulin	NASA
Muli Kifef	NASA
Vikash Srivastava	CNS

3.4. Discussion Report

The session opened with the discussion on the present frequency allocation schemes and the time line by which we will run out of frequencies. It was generally agreed that a new technology or at least a new and more efficient frequency allocation mechanism is needed.

Break out session member discussed the scope of fundamental research that was required for the successful implementation of the NExTNAS. Fundamental research in the area of communication waveform was the topic of interest. It was felt that the waveform research would be beneficial to the NExTNAS project. Along with waveform research an in-depth analysis into the filter requirements and performance, guard band were also considered to be important.

Different communication technologies were discussed for the terminal area communication requirement. It was noted that Eurocontrol has been looking into UMTS and SATCOM as a possible alternative for terminal area requirements. Latency issues related to SATCOM and its impact was discussed in the context of terminal area communication.

Test and demonstration aspect of the NExTNAS project attracted many comments and views. It was noted that implementing and demonstrating the NExTNAS project with the required research effort was a challenging but achievable target.

The anticipated required capacity for the NExTNAS project also drew some comments. It was noted that by increasing the efficiency in the AOC operation by implementing new technology and process the demand might not be as exponential as it is envisioned now. It generally agreed that a careful analysis of the capacity for the NExTNAS needs to be done.

One was of the most discussed aspect of the break out session was the scope of the NExTNAS project. Desirability, need, feasibility and requirements were discussed in detail. Mr. Mike Zernic provided valuable insight regarding the project and scope requirements.

It was agreed that at for test and demonstration purpose there should be equipment or at least a breadboard implementation of the selected technology and concept. It was general consensus that such a tangible requirement is necessary to gauge and analyze the effect of NExTNAS project.

The life cycle of NExTNAS was considered to be 20 years with implementation by year 2010. The life cycle and implementation dates were an approximation based on the current rate of technology development, congestion rate in the NAS and the frequencies available for aviation communications. The group envisioned an increase in capacity requirement by a factor of 2 to 3, at the current rate of traffic increase and 25 KHz separations of available frequency channels.

3.5. Session Out Briefing Report

The following main issues were addressed in the breakout Session B: (See **Attachment 10** for presentation charts):

- VHF Systems Optimization
- Terminal Area Communications

There were 27 attendees in the break out session with significant comments from Mitre, SITA, PMEI and Northrop Grumman. The following Brief Out Agenda was discussed and set forth to cover the desired goal of the break out session:

- VHF Systems Optimization
  - Problem Statement
  - Products
  - FY04 Subproject Approach
- Terminal Area Communications
  - Problem Statement
  - Products
  - Subproject Approach
- Parking Lot Topics

3.5.1. VHF Systems Optimization

- **Problem statement**
  Limited VHF communications system capacity and increased air traffic results in congestion of the aviation VHF spectrum. The resulting voice communication errors and delayed channel access create system congestion and air traffic delays.

- **Comments on Problem Statement**
  The group discussed the given problem statement and provided the following inputs:

  - The word "resulting" should be deleted. The second sentence was not dependent upon the first. It was felt that the errors and associated delays in the communication system were not necessarily caused by congestion.
  - Additional applications may impose more demand for VHF frequencies. For example, WAAS may generate a demand for AWOS.
  - Regulatory subdivision of bands for specific functions limits the flexibility in frequency usage. It was discussed and the consensus felt that more flexibility in channel usage might increase the capacity of the NAS system. The structure and

time line of the channel reassignment were not clear and more investigation and analysis would be required.

- **Products: Initial Products**

Following output products were envisioned for the VHF technology optimization of the NExTNAS project:

  - Technologies to improve efficiency of the VHF communication spectrum
  - VHF antennas
  - Technologies to reduce frequency guard band requirements
  - Dynamic geographic frequency allocation
  - VDL-3 system performance characterization

- **Comments on Products**: It was believed that the initial product description was not sufficient enough and the following tasks needed to be included:

  - VDL-2 system performance characterization: Instead of focusing on new technology, existing technology should also be considered. The performance characterization for VDL Mode 2 needs to be performed and benchmarked with respect to envisioned capacity requirements.

  - Technologies that optimize VHF link: Apart from research into the physical link technologies, research should also focus on various applications that would optimize the existing VHF links.

  - Cost to end-user should be taken into consideration: It was very strongly felt that which ever technology and /or solutions were being considered, the cost of their implementation and deployment should be considered. The cost to end-user may ultimately decide the feasibility of the solution

  - Radio front end may also need to be analyzed: Further research is needed in the area of radio front end

  - Additional research in the area of signal mask and filtering requirements is needed to reduce guard bands requirements and co channel interference

  - Dynamic frequency allocation should be synchronized with ATS plans for dynamic resectorization. It was felt that any dynamic frequency reuse/resectorization scheme had to be synchronized with the ATS plan for it to be practical

  - Address the policy constraints on VHF Band allocation

3.5.1.1. VHF Systems Optimization: FY04 Subproject Approach

3.5.1.2. Initial Approach

Perform technology assessment and refine concepts to down-select near term candidate technologies for further development and demonstration.

3.5.1.3. Comments on Approach

- It was the general consensus of the group that before any initial approach path was selected, the following points/tasks needed to be performed:
    - Assess and scope the problem
    - Quantify VHF spectrum capacity, congestion and interference issues in the VHF band
    - Consider technology insertion windows of opportunity
    - Parametric analysis for guard band would be needed to evaluate the benefit, so that a comparison to the real need of reducing frequency congestion could be performed

- Identify high payback candidate solutions. The solution which provides the greatest pay back should be identified and selected
- Consider both voice and data: For system research and analysis, both voice as well as data traffic should be considered
- The assessment should consider the multiple antenna subsystem versus the reconfigurable antenna subsystem

3.5.2. Terminal Area Communications

3.5.2.1. Problem Statement

Initial Problem Statement that was discussed by the group is provided below:

- Demand for digital air/ground (A/G) communications in the terminal area will continue to rapidly increase due to:
    - Increase in air traffic density
    - Advanced terminal area automation systems

- Implementation of self-separation techniques

- Long-range NAS operational concepts indicate a need for wideband terminal area communications to address the inability of current and emerging A/G systems

3.5.2.2. Comments on Problem Statement

The group discussed the problem statement provided for the Terminal Area Communications. Following inputs/suggestions were made:

- Remove "digital" since it infers a solution. It was felt that by inserting the word "digital", we may be excluding other possible solutions
- The implementation of self-separation techniques, as a driver of the increase in demand of bandwidth requirement, is questionable

3.5.2.3. Terminal Area Communications Products: Initial Products

The Next Generation Terminal Area Communications System Definition follows:

- Requirements & Technology Assessment
    - Determine communications requirements
    - Identify candidate technologies and technology gaps

- Initial System Feasibility Evaluation
    - Develop component, system proof-of-concept models
    - Proof of concept feasibility demonstration and evaluation of candidate technologies

3.5.2.4. Comments on Products

- Assess various operational and procedural concepts that are forecast for the 2015 – 2025 timeframe. Next, translate the CONOPS into system requirements
- Communications requirements analysis should consider security needs
- The magnitude of the increased communications capacity should be determined (Question: is a quantum increase in capacity needed?)
- Alternative modulation techniques and waveform designs should be considered

3.5.2.5. Terminal Area Communications: Subproject Approach

The following approach was discussed and agreed upon by the group regarding the Terminal Area Communication:

- FY04
    - Validate the problem statement as part of the requirements analysis
    - Security needs should be addressed in the solution: The security aspect of the Terminal Area Communication should be included from the start of the design, rather than as an addition on to the solution

- FY06 – 08
    - Replace references to prototypes and field demonstrations with proof-of-concept models. It was felt that the term "prototype" may be construed as a fully operational system test, rather than a working implementation model of the concept. The working proof of concept may or may not be certifiable

- FY07- 08
    - Build breadboard of key components: It was strongly felt that a physical implementation on a breadboard or physical equipment is needed. The physical implementation can be used to provide would be give tangible test and implementation results.

3.5.2.6. Parking Lot Topics

Scalability, flexibility and cost should be considered for all solutions, tests and demonstrations. The cost of the proposed solution should be kept as low as possible. Identify all relevant stakeholders and incorporate their inputs. For example, Terminal Area Operations Aviation Rulemaking Committee (TAOARC) is a stakeholder. Desired inputs on changes would be in the utilization of human resources. Test and demonstration of applications should occur in a system context. End user inputs should be included in the test and demo definitions and executions. Europe (Eurocontrol) is investigating SATCOM and UMTS technologies for use in the terminal area as a solution to future capacity problems. Frequency spectrum allocation would have to be coordinated with ITU through the WRC. It was felt that Communications, Navigation and Surveillance functions should be allowed in the same frequency band while maintaining the required safeguards. This would improve the allocation efficiency and system performance. Voice recognition technologies should be investigated to reduce the voice communications errors.

3.5.2.7. Priority From Break Out Area

The following statement was provided to the group for discussion and analysis:

> ***It's 2009, the NExTNAS-CNS Project has spent its budget and has delivered key transitions/enabling breakthroughs toward an ATM transformation because it has successfully "________________"***

The group decided that the following outcome would demonstrate the transformation was successful:

- Belief that the identified technologies would help ensure VHF Communication is not the limiting factor in ATM operation
- Industry acceptance of the NASA technology for commercial production
- Technical and regulatory communities acceptance of the proposed solutions

3.5.2.8. Priority From NExTNAS

> ***It's 2009, the NExTNAS-CNS Project has spent its budget and has delivered key transitions/enabling breakthroughs toward an ATM transformation because it has successfully "________________"***

- Industry acceptance of the proposed technologies for product development.
- NASA efforts are considered successful by key government decision makers and the aviation community, so that follow on research is funded.
- Technical and regulatory communities' acceptance of the proposed solutions.

3.6. Conclusions and Major Themes Summary

The group concluded that further research should be conducted in various categories such as: radio front end, frequency allocation scheme, filter requirements and modulation waveform. It was felt that any technology or solution that was selected should be cost effective and provide high benefits for implementation. Careful analysis of the required capacity needs to be performed. A physical implementation such as a breadboard implementation of the selected solution/technology should be available by the end of the research work. Test and demonstration of the applications should occur in a system context. End user inputs should be included in test demo definitions and executions.

4. Session C: Multi-Function/Multi-Mode Digital Avionics (MMDA)

4.1. Identification of the Session Chair(s)

Frank Mackowick (John Hopkins University / Applied Physics Lab) presided over the session as chairperson. James Budinger (NASA GRC) was the co-chair.

4.2. Purpose

The intent of the Multifunction/Multimode Digital Avionics breakout session was to carry forward the discussion from the previous ICNS Conference held May 2003 at Annapolis, MD. The session implemented a revised problem statement and generated recommendations/comments pertaining to issues on the topic.

4.3. Members

The following individuals participated in the breakout session C:

1. Frank Mackowick (John Hopkins University / Applied Physics Lab)
2. James Budinger (NASA GRC)
3. Richard Barhydt (NASA GRC)
4. Mike Bristow (iFly Air Taxi)
5. Chuck LaBerge (Honeywell)
6. Rajesh Rahavan (Analex)
7. Michael Kocin (ViaSAT)
8. Roger Herron (Lockheed Martin)
9. Chris Papachristou (CWRU)
10. Dawn Emerson (NASA GRC)
11. Monty Andro (NASA GRC)
12. Nam Nguyen (NASA GRC)
13. Afroz Zaman (NASA GRC)
14. Francis Wolff (CWRU)
15. Richard Reinhart (NASA GRC)
16. Karl Grundmann (NASA / JPO)
17. Felix A. Miranda (NASA GRC)
18. Richard Q. Lee (NASA GRC)
19. Don Moore (AeroStream)
20. Vicki Cox (FAA)
21. Crispin Netto (Computer Networks & Software)

4.4. Discussion Report

The session began with a discussion regarding the outcome of the previous ICNS Conference held May 2003 at Annapolis, MD. The problem statement for the session was then revisited and revised. Simultaneously, many members offered inputs on the various issues and technical challenges that were the core of the motivation of the MMDA. Numerous other recommendations were offered as part of the initiative in developing MMDA architecture. These are outlined in Section 4.5.

4.4.1. Comments on ICNS May 2003 Out brief on Software Defined Radio (SDR)

The following were the comments regarding the previous ICNS Conference:

- Technical challenges need to be elaborated (e.g., bandwidth, dynamic range, radio functionality, end-user applications)
- RTCA SC 200 should be consulted for possible involvement in MMDA
- Relevant AEEC subcommittee(s) should be consulted for possible involvement in MMDA
- Backward compatibility with existing waveforms should be easy to accomplish due to their simplicity relative to recent and emerging waveforms
- Business case is uncertain for an open platform standard vs. allowing proprietary solutions to evolve

4.4.2. Revised Problem Statement

In addition to the current problem statement, the following were added:

- Existence of multiple national standards
- Expensive to certify and upgrade/recertify a new MMDA SDR
- Lack of reconfigurability

The group also defined additional issues that were core to the motivation for the MMDA:

- The accelerating pace of new waveform development and the difficulty of retiring legacy waveforms, is beginning to overwhelm the ability of aircraft manufacturers and operators to fit the aircraft with new capabilities
- Need for a new, cost-effective methodology to certify avionics: both for initial product certification and for subsequent certifications when new waveform functions are added to an existing product

4.4.3. Other Discussion Points

- The investment required for software certification may negate the original advantage of creating a SDR
- Need for an evolutionary roadmap that would use the SDR to facilitate movement towards RTSP, and for overall MMDA architecture to include secure onboard networking and routing capabilities
- Consider a parallel effort to explore supporting antenna technology
- A program to develop and fully evaluate a multi-mode prototype in an operational environment could cost as much as $20M
- Consider fostering the development of core technologies useful to any MMDA manufacturer. (e.g., current high-resolution A/D converters provide 14 bits @ 100 MHz; the goal is to provide 20 bits @ 100 MHz)

4.5. Session Out Briefing Report (The briefing material is provided in **Attachment 11**)

The following were the recommendations of the MMDA Session C:

- Focus on multi-mode communications as a starting point for multi-function avionics (e.g., communications for C, N, and S)
- Build on existing JTRS multi-mode standards and architecture (leverage JTRS developed waveforms and algorithms); but don't plan to mandate
- Standards should be detailed enough to fully specify requirements to ensure interoperability without stifling manufacturer innovation
- Information security should be a prime consideration in developing a MMDA architecture
- Consider defining broad collections of functional capabilities that can be rolled into specific MMDA equipment classes. (e.g. Rx-only vs. Tx/Rx, Simultaneous vs. Sequential modes, etc.)
- First phase (FY04-FY05) work should concentrate on necessary "homework" to validate the need to invest in research, standards development, and prototype development
- Coordinate with relevant RTCA and AEEC activities (e.g., SC-200) for possible interest in new standards work

In addition to the above recommendations, the group envisioned a successful implementation of the MMDA project if:

- It fosters development of a cost-effective certification process
- It has demonstrated a prototype that is of value to the industry
- It has transferred relevant technology to the industry

Other key aspects critical to the NExTNAS-CNS project delivering transitions/enabling breakthroughs toward an ATM transformation are:

- Preservation of spectrum and optimization of its use
- Enabling cost-effective MMDA products capable of utilizing optimized spectrum
- Fostering the migration toward a Global A/G network

4.6. Conclusions and Major Themes Summary

The MMDA Session C provided a forum to discuss the conceptualization and development of a MMDA Software Defined Radio. Numerous individuals representing various facets of industry participated in the session to formulate a roadmap for building a MMDA SDR.

The group revisited the problem statement and generated a revision, in addition to providing recommendations and suggestions to be dealt within various industry groups. A summary of the major highlights of the session include:

- Comments regarding the ICNS May 2003 Outbrief on SDR
- Revised problem statement
- Recommendations
- Other discussion points
- Integration team questions

5. Session D: Oceanic C & S and Future Space Based Surveillance

5.1. Overview of the Workshop Breakout Sessions

Session D of the 3rd ICNS Conference and the NExTNAS-CNS Workshop centered discussions on two main topics. The first half of the breakout session involved Oceanic Communications/Surveillance as it related to air transportation. The second half of the session focused on areas that Future Space-Based Surveillance may apply to aviation.

5.2. Identification of the Session Chair(s)

Gus Martzaklis served as Chairperson while Ricardo Parra was the Co-Chairperson.

5.3. Purpose

The purpose of the Oceanic Communications/Surveillance breakout session was to discuss the development and ascertain the demonstration of affordable components and system technologies that may generate cooperative surveillance, direct pilot-controller communication, and pertinent weather information. The goal is to enable safe oceanic spacing reductions to 30/30 nm with potential future reduction to 15/15 nm.

Another goal of the Future Space-Based Surveillance breakout session was to identify space-based technologies that can provide high-resolution surveillance information in all airspace with uniform coverage. This also involved investigating the benefits and cost of technology enhancements for space-based radar, multilateration and satellite-based ADS/TIS to improve system performance.

5.4. Discussion Report

The discussions centered on oceanic and remote regions that have no direct communications or surveillance capabilities, requiring aircraft distance spacing up to 60 NM for safe operations and resulting in major operational inefficiencies. Additionally, accurate and precise aircraft position is not uniformly available in all places through the present cooperative and non-cooperative surveillance capabilities. Constraints in system capacity have resulted in the inability to reduce aircraft separation minima.

Both groups (Oceanic and Space-Based) identified a need to clarify each problem statement with known facts that related to current or near future technology advancements. Therefore, the problem statements were modified as the discussions unfolded. The group agreed that test and demonstrations were needed to address problems in Oceanic and Remote areas, but questioned what are the economics, benefits and alternatives for requisitioning such programs. In addition, the REDAC Committee Working Group has not met on this subject since November 2002.

In summary, the group was aware that the Airline Training Operation Program (ATOP) was geared towards lowering the reversed vertical separation minima. At present, the group agreed that there were no economical or reliable communications services available to satisfy the needs related to this problem.

As far as space based surveillance was concerned, the question arose whether there were sufficient concepts in place to start this objective. The group also questioned if an ATC satellite constellation was a viable solution, to also include weather.

5.5. Session Out Briefing Report

The session out briefing reports presented for Oceanic and Space-Based surveillance can be found in **Attachment 12**.

The group recommended performing a feasibility study of space-based surveillance in FY04 to target and align planned goals toward a 2008 time frame.

5.6. Conclusions and Major Themes Summary

The group recognized that ADS and Data-link may be required to achieve maximum benefits. They also decided that there were no economical or reliable communications services for oceanic and remote region airborne surveillance. The group suggested that cost and equipment models would be needed to enhance and better understand the problem.

It was also noted that AWIPS II may have technology capabilities, or room to include additional needed capabilities.

5.7. Conclusions and Summary

5.7.1. Oceanic Communications/Surveillance

The working group determined that an investigation should be conducted to determine the current limits in architecture and technology, for airborne separation reduction offshore and in remote locations. The group determined that satellite based ADS should also be investigated to meet separation goals.

The short-term goal would be to determine terms and conditions of current and near future communications satellites and also investigate lower cost avionics. As noted in the workshop out briefing (**Attachment 12)**, the work being conducted from the GoM SATCOM trials by GCNSS/Boeing and relevant activities should be leveraged. The long-term goal would be either government owned and operated SATCOM, or Satellite to ADS-B hybrid schemes.

5.7.2. Future Space-Based Surveillance

The Working Group recommended that NASA/NRO/Other Appropriate Agencies host a TIM to address the capabilities of space-based surveillance as it relates to potential aviation applications.

The group recognized the need to evaluate Spaced Based Radar activities by NRO/DoD and DHS/NASA Aviation Security for possible ATC applications. This should include investigating improved satellite weather sensor technologies for ATM, by leveraging FAA, AWRP and NASA aviation weather research programs.

6. Session E: Surface Integrated CNS Network

6.1. Identification of the Session Chair(s)

This session was chaired by Marty Pozesky (MTP Assoc.) with Ralph Apaza, (FAA) acting as the co-chair.

6.2. Purpose

Currently, surface networks use VHF communications for voice only (no data). These networks are limited in their capabilities to enable future system automation and decision support systems. In addition, these networks use an aging, obsolete, physical communications infrastructure that is vulnerable to outages and costly to maintain and upgrade.

The purpose of this session was to obtain industry input regarding developing and demonstrating a wireless surface integrated CNS network prototype that enables:

- Transfer of mission critical airport voice/data among users and service providers
- Transfer of non-critical information among aircraft, tower, airport and airline operators
- Interoperability with existing and future systems
- Required redundancy and reliability
- Scalability, flexibility and upgrades

6.3. Members

The following individuals participated in breakout session E:

1. Marty Pozesky (MTP Assoc)
2. Rafael Apaza (NASA/FAA)
3. Manu Khanna (CNS)
4. Jim Hurlburt (Mulkerin Assoc)
5. Chris Bartone (Ohio U)
6. Duc Ngo (NASA)
7. Lynne Weuberg (Boeing)
8. George Coulubis (Seagull Tech)
9. Dave Whitaker (Sensis)
10. Jennifer Lamont (TRIOS Assoc)
11. Terry Bell (Lockheed-Martin)
12. Karen Bricker (AMTI)
13. Phil Carrigan (Raytheon)
14. Jim Griner (NASA)
15. Harold Brackett (Harris)
16. Lawrence Robinson (Boeing)

6.4. Discussion Report

The major point of initial discussion in the breakout session was centered on the objectives of the session. It was the consensus of the group that the discussion should not be limited to wireless technology alone, and other non-wireless technologies must be included. As a result, the group refined the original problem scope.

In the following discussion, the group followed the outline provided by Robert Kerczewski to address various aspects of the problem and objectives. The group identified other relevant work in the area. It also identified desired collaborators for the efforts. A progressive testing methodology was recommended to test and integrate in small steps.

The group strongly felt that any technology developed must be based on open standards and must also be robust enough to meet the stringent safety requirements. Scalability was also very desirable given the diverse environments in which the technology may be deployed. Finally, security concerns were addressed.

Near the end, the discussion emphasized the question of who was the real customer of NASA. It was strongly felt that NASA needs to think beyond the traditional "FAA as a customer" and must invite participation by the end users of the technology.

6.5. Session Out Briefing Report

Chairperson Marty Pozesky (MTP Assoc.) presented the briefing at the Out brief session (Attachment 13). The presentation included all the major points discussed in the breakout session. There were no questions from the audience.

6.6. Conclusions and Major Themes Summary

The following were comments and a summary of the session:

- Any technology developed must be robust, scalable, secure and based on open standards
- NASA needs to think beyond the FAA. Participation by and buy-in of end users is critical to the success of developed technologies
- The degree to which the developed technologies are adopted by the user community will be a key success metric of these efforts
- Although not an R&D issue, a business case must be made for developing Surface ICNS technologies. Business viability will be a key factor in ultimate adoption of these technologies by the end users and service providers
- Finally, the end product of the efforts will be expected to be a "Standard", supported by a Proof-of-Concept

7. Session F: Aviation Spectrum Issues and Solutions

7.1. Identification of the Session Chair(s)

John Zuzek – NASA
David Matolak – Ohio University

7.2. Purpose

The purpose of this session was to perform research and development on improved spectrum efficiency to meet current and long-term aviation requirements; while coordinating and collaborating with relevant aviation spectrum authorities, to protect aviation spectrum resources.

7.3. Members

The following individuals participated in Break out session F:

1. Paul Meredith (Computers, Networks, and Software, Inc.)
2. Diane Revell (Boeing-Connexion)
3. Mike Biggs (FAA/ASR)
4. John Zuzek (NASA)
5. Ben Nowlin (NASA)
6. David Matolak (Ohio University)
7. Kue Chun (NASA)
8. Chuck LaBerge (Honeywell)
9. Robert Crow (AirNav, Inc.)
10. Chuck Sheehe (NASA)
11. Frank Frisbie (Northrop Grumman)

7.4. Discussion Report

At the beginning of the session, the product description was reviewed and problems with the current spectrum were discussed. The group determined that many of the new aeronautical technologies must go into the current AM(R)S spectrum that do not meet the definition of radio navigation.

The group then discussed ways to solve this issue. The first solutions fit under the category of using existing aeronautical bands to alleviate the problem. The DME band (960-1215MHz) was discussed in great detail. The group next discussed the advantages and disadvantages of this band. The next solution involving the use of existing aeronautical bands was the more efficient use of the (5091-5150) MHz band. This was a top priority since this spectrum may be lost in the future.

The group then discussed solutions that fit under the category of possibilities for more efficient use of the current spectrum. The group agreed that interference mitigation and new antenna technologies should be studied.

The group discussed other issues pertinent to the spectrum discussion and determined the criteria for success of the spectrum subproject.

7.5. Session Out Briefing Report (See **Attachment 14** for presentation charts)

The DME band was an example of an existing aeronautical band that may alleviate the problem. This band may provide many aviation functions, such as collision detection, avoidance and weather surveillance. The advantages of this band included the ability to combine the aviation functions into one band. The disadvantages of this band mainly involved interference, which included GPS/Galileo and JTIDS. More research should be done on the DME band, especially on the spread spectrum overlay of DME.

The (5091-5150) MHz band is another existing band that may be used. This was a top priority since this spectrum may be lost in the future. This band is currently being reviewed by the FAA for terminal area communication and is on the WRC agenda for 2007. The (5091-5250) MHz band may use a channel scheme that uses guard bands for fixed links.

The next set of solutions are possibilities for more efficient use of the current spectrum. Interference mitigation and new antenna technologies should be studied. ILS/VOR bands overlay should also be studied for potential use. The review of the DME/ILS/VOR channel-pairing scheme may determine if uncoupling those systems would lead to more efficient spectrum use.

Other issues pertinent to the spectrum discussion include: 1) a study of current satellite frequency allocations that will support the modernization of civil aviation telecommunication systems, and 2) an examination of NExTNAS developed technologies and concepts for long-term aviation spectrum requirements. The importance of this examination is that it would show a justification for keeping what is available now and expanding the spectrum. Also, this effort would provide a long view beyond 2025 to support allocation or reallocation, and would allow for the consideration of global use of the frequency allocations.

The criteria for success of the spectrum subproject would be that the MLS band is protected and utilized for new aviation applications and that sufficient aviation spectrum is available for the future of CNS. The status of the entire NExTNAS project will depend on the success of the spectrum subproject.

7.6. Conclusions and Major Themes Summary

There are many approaches to solving the spectrum issue that fit into two main categories: 1) alternative or shared use of existing aeronautical bands and more efficient use of the current spectrum; and 2) more research needs to be done on bands such as DME and ILS/VOR. Also, the long-term aviation spectrum requirements of NExTNAS technologies should be examined. Most importantly, the spectrum issue is paramount to the success of the entire NExTNAS project.

V. CONCLUSIONS AND SUMMARY

Bob Kerczewski thanked everyone for their participation throughout the entire workshop. He also thanked those support individuals and the chair people for their time and energy extended to enable this workshop to be very successful.

VI. ATTACHMENTS

Attachment 1: NExTNAS – CNS Workshop Agenda

Attachment 2: Attendee List

Attachment 3: Workshop Overview and Objectives

Attachment 4: Airspace Systems Overview

Attachment 5: FAA/NASA/IAIPT Overview

Attachment 6: FAA Target Systems Description

Attachment 7: NExTNAS – CNS Project Overview

Attachment 8: Session A: CNS Architectures and Networks

Attachment 9: Session B: VHF System Technology and Next Generation Digital Communications

Attachment 10: Session C: Multi-Function/Multi-Mode Digital Avionics

Attachment 11: Session D: Oceanic Communications/Surveillance and Future Space-Based Surveillance

Attachment 12: Session E: Surface Integrated CNS Network

Attachment 13: Session F: Aviation Spectrum Issues and Solutions

Attachment 14: Acronym List